

## ORIGINAL RESEARCH

# THE NAVICULAR POSITION TEST – A RELIABLE MEASURE OF THE NAVICULAR BONE POSITION DURING REST AND LOADING

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## ABSTRACT

**Background:** Lower limb injuries are a large problem in athletes. However, there is a paucity of knowledge on the relationship between alignment of the medial longitudinal arch (MLA) of the foot and development of such injuries. A reliable and valid test to quantify foot type is needed to be able to investigate the relationship between arch type and injury likelihood. Feiss Line is a valid clinical measure of the MLA. However, no study has investigated the reliability of the test.

**Objectives:** The purpose was to describe a modified version of the Feiss Line test and to determine the intra- and inter-tester reliability of this new foot alignment test. To emphasize the purpose of the modified test, the authors have named it The Navicular Position Test.

**Methods:** Intra- and inter-tester reliability were evaluated of The Navicular Position Test with the use of ICC (interclass correlation coefficient) and Bland-Altman limits of agreement on 43 healthy, young, subjects.

**Results:** Inter-tester mean difference -0.35 degrees [-1.32; 0.62] p = 0.47. Bland-Altman limits of agreement -6.55 to 5.85 degrees, ICC = 0.94. Intra-tester mean difference 0.47 degrees [-0.57; 1.50] p = 0.37. Bland-Altman limits of agreement -6.15 to 7.08 degrees, ICC = 0.91.

**Discussion:** The present data support The Navicular Position Test as a reliable test of the navicular bone position during rest and loading measured in a simple test set-up.

**Conclusion:** The Navicular Position Test was shown to have a high intraday-, intra- and inter-tester reliability. When cut off values to categorize the MLA into planus, rectus, or cavus feet, has been determined and presented, the test could be used in prospective observational studies investigating the role of the arch type on the development of various lower limb injuries.

**Key Words:** Foot, Feiss Line, reliability, alignment, pronation

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Statement of the Institutional Review Board approval:  
KF:01-045/03

## INTRODUCTION

Overuse injuries in the lower extremity are numerous, costly, and represent a large clinical problem.<sup>1-2</sup> Despite the extent of the problem, there is a paucity of knowledge on the cause of the injuries.<sup>3-6</sup> Meeuwisse et al.<sup>7</sup> published a dynamic model of etiology in sport injury where exposure to an injury is the result of a combination of possessing a risk factor and then participating in events with lesser or greater degrees of risk involved. The function and structure of the medial longitudinal arch (MLA) of the foot has been proposed as a risk factor for developing injuries.<sup>8-10</sup> Increased navicular drop (ND) has been determined to be a risk factor for sustaining injuries among female novice runners when preparing for a four mile running event.<sup>10</sup> Along the same line, different arch structures have been found to be associated with specific injury patterns with high arched runners reporting a greater incidence of ankle injuries, stress fractures of the fifth metatarsal and iliotibialband friction syndrome.<sup>11</sup>

In general low arched runners exhibited more knee pain, patellar tendinitis and plantar fasciitis.<sup>8</sup> This is supported by several studies demonstrating an increased ND to be associated with a greater risk of developing exercise related lower leg pain and patellofemoral pain syndrome.<sup>9,12</sup> However, no clear link between foot posture and injury likelihood exists<sup>13-15</sup> and instead other risk factors are suggested as potential deleterious and main cause of the injuries. One reason for discrepancy may be the result of the lack of reliable and valid field methods of determining the MLA and biomechanical characteristics of the foot during loading.

Visual assessment of MLA has been proposed<sup>16</sup> but found not to be reliable and valid.<sup>17,18</sup> As a consequence, different static tests have been developed to attempt to quantify the position of MLA<sup>19-22</sup> including the Navicular Drop Test and the Arch Index. These methods have been proven to be valid and reliable<sup>23-26</sup> but despite their validity they do not take into account the effect of foot sizes on the relative drop of the navicular bone<sup>27</sup> which may lead to misinterpretations when used in a mixed population as in a normal clinical setting. The Feiss Line test<sup>2,28</sup> has been suggested to be a valuable tool as it relates to the position of the navicular during rest and loading in

relation to the line between the medial malleolus and the first metatarsal head rather than to the height of the ND during loading. In addition the Feiss Line test is easy to conduct and requires no additional measuring devices apart from a pen and goniometer. Furthermore, the test does not require identification of the subtalar neutral position. This is recommended since the exact localisation of neutral position is extremely difficult and not reliable.<sup>29</sup>

Recently, McPoil<sup>30</sup> described the difficulty in the identification of the neutral position as a possible factor contributing to the moderate levels of inter-rater reliability provided by the ND test. However using the Feiss Line test it is possible to quantify the MLA using a simple setup, without the need for identification of subtalar neutral position. The Feiss Line is defined as an imaginary straight line from the medial malleolus through the navicular bone to the center of the head of the first metatarsal.<sup>2</sup> For the purposes of this study the original Feiss Line test had to be modified to increase the accuracy and usefulness of the test in clinical practice. This requires that the navicular in a neutral foot is positioned upon the modified Feiss Line. By changing the position of one end of the Feiss Line from the original position on the medial malleolus to a parallel shifted point on the Achilles tendon and retaining the original point from the Feiss Line on the first metatarsal head, a resultant lowering of the Feiss Line occurs. Thus, the navicular is placed on the line in the neutral foot. This makes the definition of pes rectus, pes planus and pes cavus easier for clinicians, as the navicular is placed below and above the new Feiss line in low or high arched individuals, respectively. Before the new line can be recommended to clinicians and applied in research and clinical work it has to be tested for reliability and validity.

The aim of the present study was to describe the modified Feiss Line and to determine the intra- and inter-tester reliability of this new Navicular Position Test (NPT). In the current study no attempt was made to establish validity of the NPT.

## METHODS

All participants in this study were volunteers at a large badminton tournament in Denmark [n = 43; 17 women and 26 men; age 23 y (18 to 40 y)]. The study



**Figure 1.** The set-up of The Navicular Position Test.

was approved by the Ethical Committee KF:01-045/03. The participants were tested by inexperienced physiotherapy students three times, twice by the one clinician and once by the other to determine the within day intra- and inter-tester reliability. The examination was conducted in two separate rooms, allowing no communication and ensuring that all data was blinded for the assessors. Following the measurements the markings on the foot were removed completely with alcohol by a third researcher allowing the clinicians to be fully blinded. Randomizing the order of the participants when retesting further ensured blinding in the intra-tester assessment.

The test measurements were conducted on the right foot only. The participant stood in an upright position, toes pointing straight forward, with the right foot behind the left with the left heel and right toe on the same transverse plane. The right knee was placed vertically above the first and second toe (Figure 1). The subjects were allowed to hold a metal stick for support. The clinician marked the medial side of head of the first metatarsal bone, then the navicular tuberosity, and finally a point at the Achilles tendon (Figure 2). Marking the Achilles was done by marking the apex of the medial malleolus, then measuring the height from the floor and projecting posteriorly to a point horizontal to the dorsal edge of the Achilles tendon.



**Figure 2.** Showing markings on the foot performing the The Navicular Position Test.

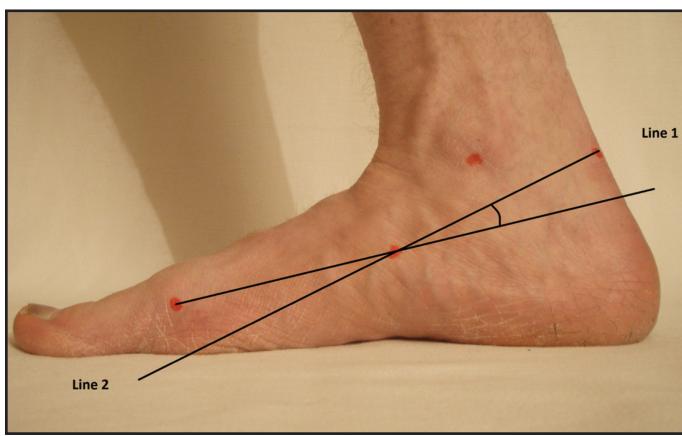
The position of the navicular bone was measured with the center of the goniometer on the navicular tuberosity and the arms of the goniometer on the head of the first metatarsal and the marking on the Achilles tendon, respectively (Figure 3). The angle between two visualized straight lines; 1) between the head of the first metatarsal bone and navicular tuberosity and 2) between the marking on the Achilles tendon and the navicular tuberosity (Figure 4). The increment of measurement of the goniometer used in this study was 2.5 degrees.

#### STATISTICAL METHODS

Interclass correlations coefficients (ICC (3,k)) were calculated in order to compare the relationship between measures. Bland and Altman's 95% limits of agree-



**Figure 3.** Measuring the Navicular Position Test with a goniometer as described in text.

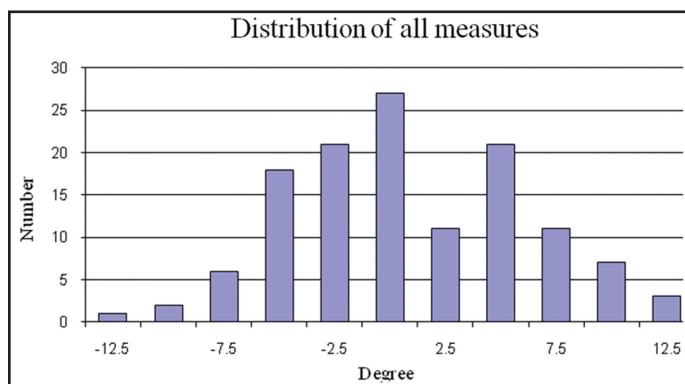


**Figure 4.** Angle measured with a goniometer in the Navicular Position Test, the two lines indicating the angle to be measured with the goniometer centered on the navicular tuberosity.

ment were used as statistical method to evaluate the agreement of the measures. Bland-Altman plot of the differences against average of the two measurements for each of the trials did not show any sign of differences or variation size depending systematically on the mean. Histogram and probability plot of the differences had a satisfactorily agreement with a normal distribution. Comparisons of the different examiners were therefore calculated based on a paired t-test. A result was considered statistically significant at  $p \leq 0.01$ .

## DESCRIPTIVE RESULTS

The distribution of the NPT measures on the 43 participants was relatively symmetric (Figure 5). The feet measured ranged from -12.5 to 15 degrees and the mean value for the total number of measures was 0.91 degrees (95% CI = -0.03 to 1.85) (Table 1). The pes planus foot displays a negative number and a pes



**Figure 5.** The distribution of total number of measures from both clinicians, all three measures from each participant. Zero degrees represents a straight line and a neutral foot, negative numbers represent a pes planus foot, and positive numbers represent a pes cavus foot.

**Table 1.** Descriptive Data for all subjects ( $n=43$ ), for Raters 1 and 2.

	Clinician 1 Test 1	Clinician 1 Test 2	Clinician 2 Test 1	Total
Number (n)	43	43	43	129
Mean degrees (Range)	0.87 (-0.73 – 2.47)	0.76 (-0.76 – 2.28)	1.10 (-0.81 – 3.01)	0.91 (-0.06 – 1.88)
Variance	27.05	24.27	38.48	29.49
Standard deviation (SD)	5.20	4.93	6.20	5.43
Standard error (SE)	0.79	0.75	0.95	0.48
SE corrected	1.6	1.52	1.91	0.97
Skewness (SE)	0.12 ( $\pm 0.36$ )	0.16 ( $\pm 0.36$ )	0.24 ( $\pm 0.36$ )	0.21 ( $\pm 0.21$ )
Kurtosis (SE)	-0.72 ( $\pm 0.71$ )	-0.11 ( $\pm 0.71$ )	-0.48 ( $\pm 0.71$ )	-0.40 ( $\pm 0.42$ )

cavus foot displays a positive number, while a neutral foot would display a straight line.

## RELIABILITY

ICC value for intra-rater reliability was 0.94 with a range of 0.88 – 0.97, while inter-rater reliability was 0.91 with a range on 0.83 – 0.95. Spearman's rho mean value of the degree of agreement between the two clinicians,  $R^2$ , Bias, and Standard Deviation (SD) of the Bias was calculated (Table 2). The intra- and inter-rater agreement was calculated using Bland-Altman plot with 95% limits of agreement (Table 3).

For the intra-rater reliability the mean and standard deviation of the difference between measurements was estimated to 0.47 (-0.57; 1.50) degrees and SD = 3.37 degrees.

**Table 2.** Correlation of Intra- and Inter-rater reliability.

	Spearman's rho Mean	P value (two-tailed)	Agreement	R <sup>2</sup>	ICC (Range)	Bias	SD of the Bias
Intra-observer reliability	Clinician 1 Test 1 vs. Clinician 1 Test 2	0.88	P<0.01	37 %	0.79 0.94 (0.88 – 0.97)	0.12	2.50
Inter-observer reliability	Clinician 1 Test 1 vs. Clinician 2 Test 1	0.87	P<0.01	33 %	0.77 0.91 (0.83 – 0.95)	-0.23	3.31
	Clinician 1 Test 2 vs. Clinician 2 Test 1	0.91	P<0.01	33 %	0.82 0.91 (0.84 – 0.95)	-0.35	3.16

**Table 3.** Bland-Altman plot with 95% limits of agreement in degrees. Positive numbers represent a pes cavus foot and negative numbers a pes planus foot.

	95 % Limit of agreement	
Agreement within the same clinician	-6.15	7.08
Agreement between clinicians	-6.55	5.85

Prediction interval (Bland-Altman limits of agreement) was -6.15 to 7.08 degrees. The mean difference estimated to -0.35 (-1.32; 0.62) degrees and SD = 3.16 degrees with prediction interval between -6.55 to 5.85 degrees. The differences were not statistically different from zero in any of the two cases ( $p = 0.37$  and  $0.47$ ).

## DISCUSSION

The purpose of this study was to examine the within day intra- and inter-rater reliability of the NPT. The test was conducted by measuring the position of the navicular tuberosity relative to markings on the head of the first metatarsal bone and the height of apex medial malleoli projected posteriorly to the Achilles tendon. High values of ICC in both intra- and inter-rater reliability were found:  $ICC = 0.94$  (0.88 – 0.97) and  $ICC = 0.91$  (0.83 – 0.95) respectively. In 95% of the measurements the same clinician can measure within -6.15 to 7.08 degrees while different clinicians measure within -6.55 to 5.85 degrees.

For clinicians it is important to select measurements of MLA which demonstrate a high degree of intra-rater and inter-rater reliability.<sup>31</sup> The current study used inexperienced physical therapy students to conduct measurements. Previously, authors who have investigated the reliability of other measures of the MLA have shown poor reliability if the tests were conducted by inexperienced clinicians<sup>32</sup> while the reliability improved with increasing experience.<sup>12</sup>

A clear strength of the approach used in this study is the high reliability despite the low experience of the examiners performing the measures. This makes the test applicable to use in the clinical setting regardless of the experience of the clinicians. Furthermore, the test is easy to use and quickly performed which gives it strength as a clinical test where both time and reliable evaluation for diagnostic and preventive purposes are of great importance.

In the selection of an appropriate foot structure assessment method, the procedure should not only provide a measurement of static foot posture but also ideally allow the clinician to predict dynamic foot posture during activities such as walking and running. The longitudinal Arch Angle (LAA), a measure almost similar to the NPT, has shown to be predictive to the dynamic MLA in midstance during walking<sup>33</sup> and running.<sup>22</sup> Similar predictive values of the the

NPT during walking and running may exist. However, this has to be investigated in future studies.

It must be emphasized, that soft tissue variation due to the amount of fat mass may mislead the clinician to evaluate the foot as pes planus even though the bony structures are in a neutral position if the MLA is evaluated visually without quantitative measures. Visual assessment of the arch height has been found to be unreliable, illustrating the need for objective standards and quantitative methods.<sup>16</sup> Using easily identifiable bony landmarks was an attempt by the authors of this paper to increase reproducibility by providing testing standards. Moreover assessment that utilizes the navicular bone may provide a better indication of typical foot function during walking as compared to classic rear-foot assessments.<sup>34,35</sup>

One limitation of the present study is the studies rather small sample size ( $n=43$ ) that consisted of active badminton players that may, despite the relatively normal distribution, not be representative of the majority of people. Subjects were both symptomatic and asymptomatic in regard to lower extremity which makes the sample likely to represent a broad spectrum of foot types. The mean foot measurement in this study was 0.91 degrees or slightly pes cavus, as the pes cavus foot displays a positive number and a pes planus foot displays a negative number.

The authors of this study made no attempt to establish numerical classification of foot types using this measurement. In order to establish limits or guidelines for meaningful classification of foot types and to assess whether the presented values agreement are of sufficient accuracy further studies need to be performed. Such studies examining the difference between pathologic and non pathologic feet, with a broader range of subjects are needed. When cut off limits are determined, prospective studies on healthy subjects could be conducted to investigate if time to injury differs among persons with different arch heights or foot types. Such studies may provide new insight about the possible role of certain foot types as a risk factor leading to injury in the lower extremity.

## CONCLUSION

The NPT described and examined in this study has an within day intra-tester- and inter-tester reliability, measured by the Intraclass Coefficients of 0.94

and -0.91, respectively. In 95% of the measurements the same clinician can measure within -6.15 to 7.08 degrees while different clinician's measure within -6.55 to 5.85 degrees. The mean value of the NPT measurements performed was 0.91 degrees. This suggests that the NPT would be very easy to use in the clinic as the average or neutral foot will have the three NPT marks aligned very close to a straight line. The NPT is a simple test that can be used to clinically evaluate the position of the navicular bone in a weight bearing position. Future studies must be conducted to establish cut off limits to categorize the foot into planus, rectus, and cavus foot types. Then, prospective studies can be conducted to investigate if athletes with planus and cavus feet are at higher risk for sustaining injuries when compared athletes with a rectus foot.

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